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(54) **CRYSTAL ELEMENT AND CRYSTAL DEVICE**

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(51) **Int. Cl.**

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H01L 41/053	(2006.01)
H03H 9/17	(2006.01)
H03H 9/10	(2006.01)

(52) **U.S. Cl.**

CPC ***H03H 9/02157*** (2013.01); ***H01L 41/053*** (2013.01); ***H03H 9/1021*** (2013.01); ***H03H 9/17*** (2013.01); ***H03H 9/177*** (2013.01)

(58) **Field of Classification Search**

CPC H03H 9/17; H01L 41/053; H01L 41/0933; H01L 41/094

See application file for complete search history.

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(57) **ABSTRACT**

The crystal element includes: a mesa-shaped crystal piece in a substantially rectangular shape in a plan view including an oscillation section having a first protruded section and a second protruded section; excitation electrodes provided on both main surfaces of the oscillation section; leading sections provided side by side along a prescribed side of the crystal piece; and a wiring section connecting between the excitation electrodes and the leading sections. The first protruded section and the second protruded section include sloping side faces. The side face of the first protruded section located on the +X-side overlaps with the side face of the second protruded section located on the +X side, and the side face of the first protruded section located on the −X-side overlaps with the side face of the second protruded section located on the −X side.

5 Claims, 6 Drawing Sheets

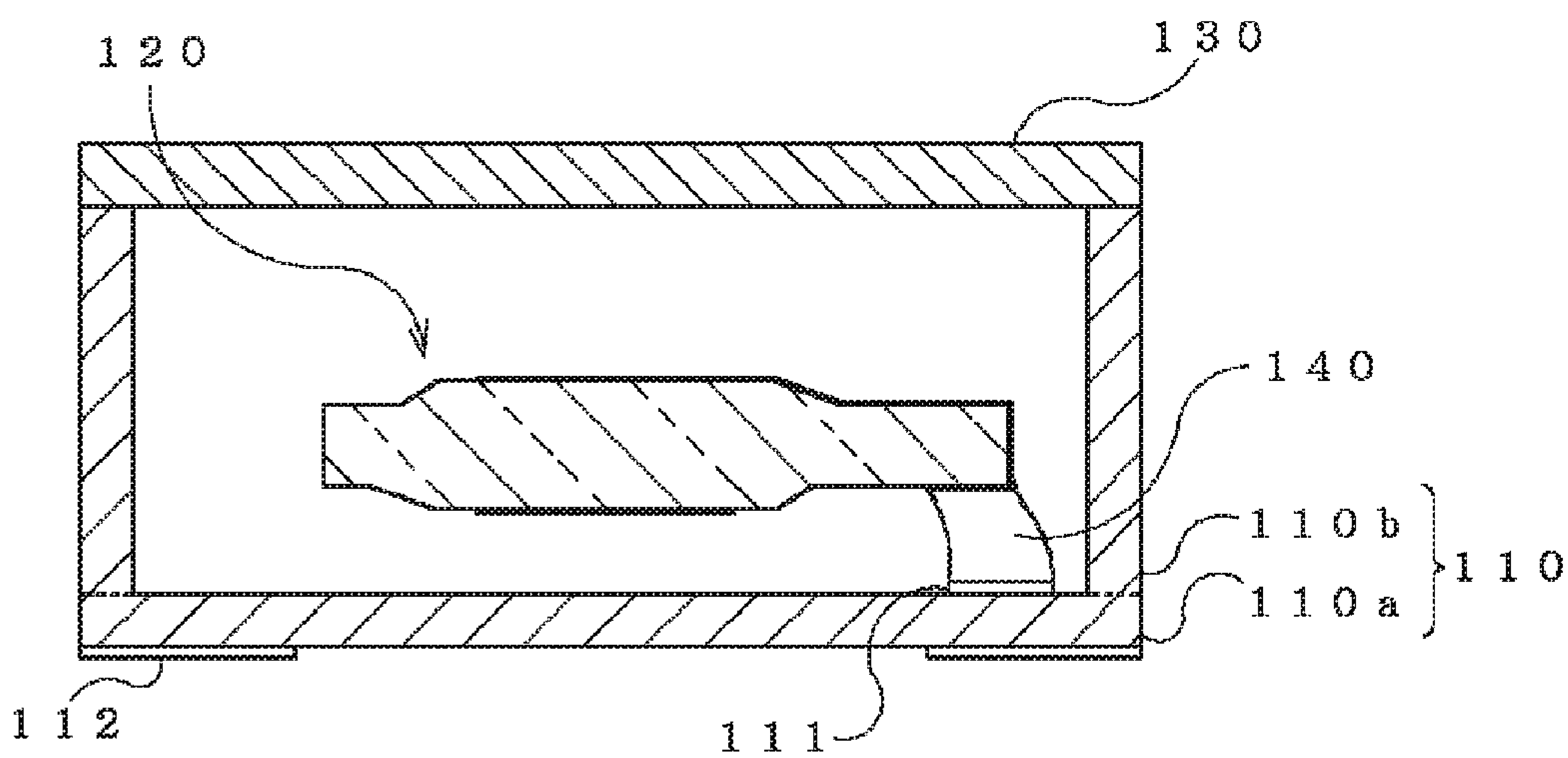

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FIG.1

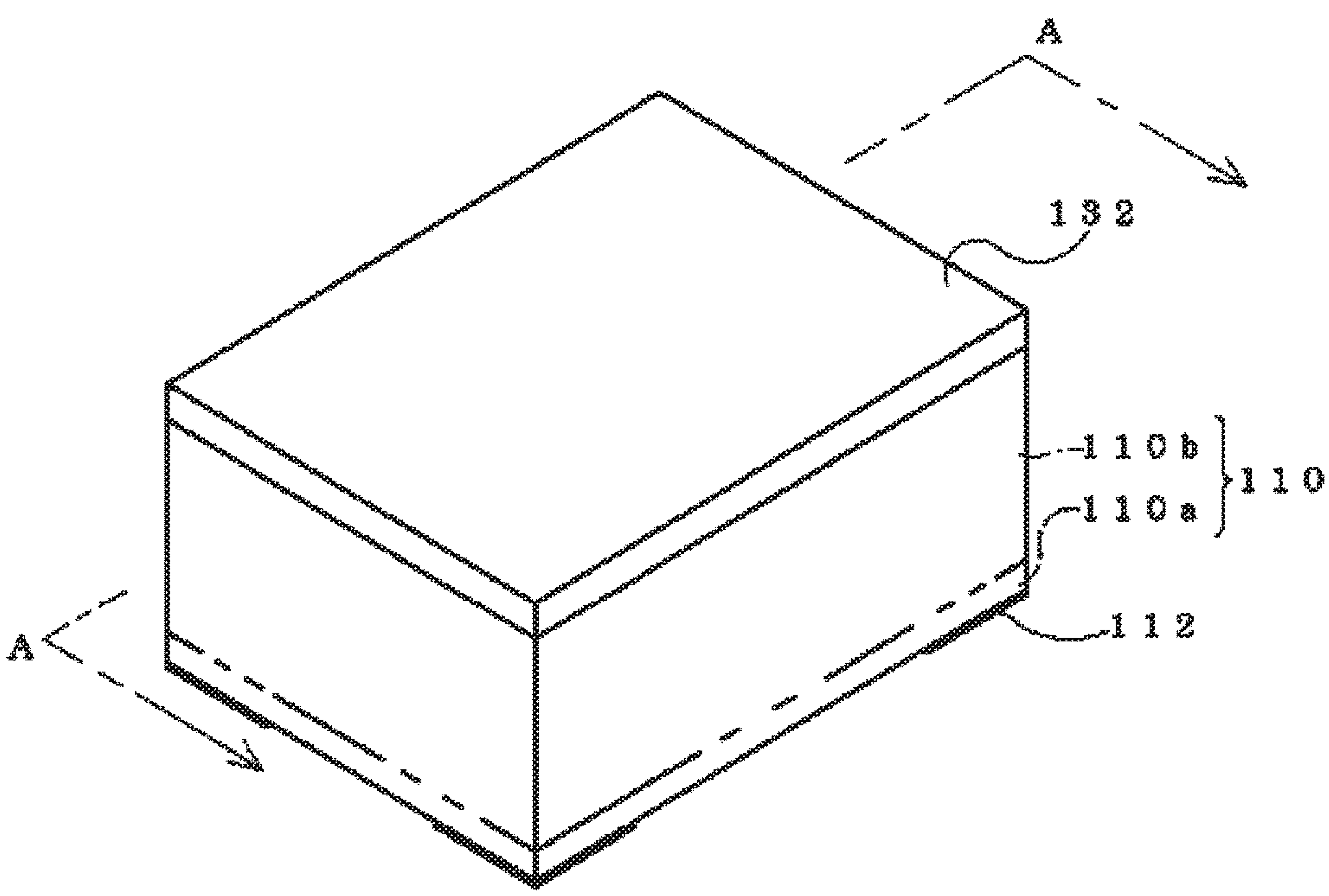


FIG.2

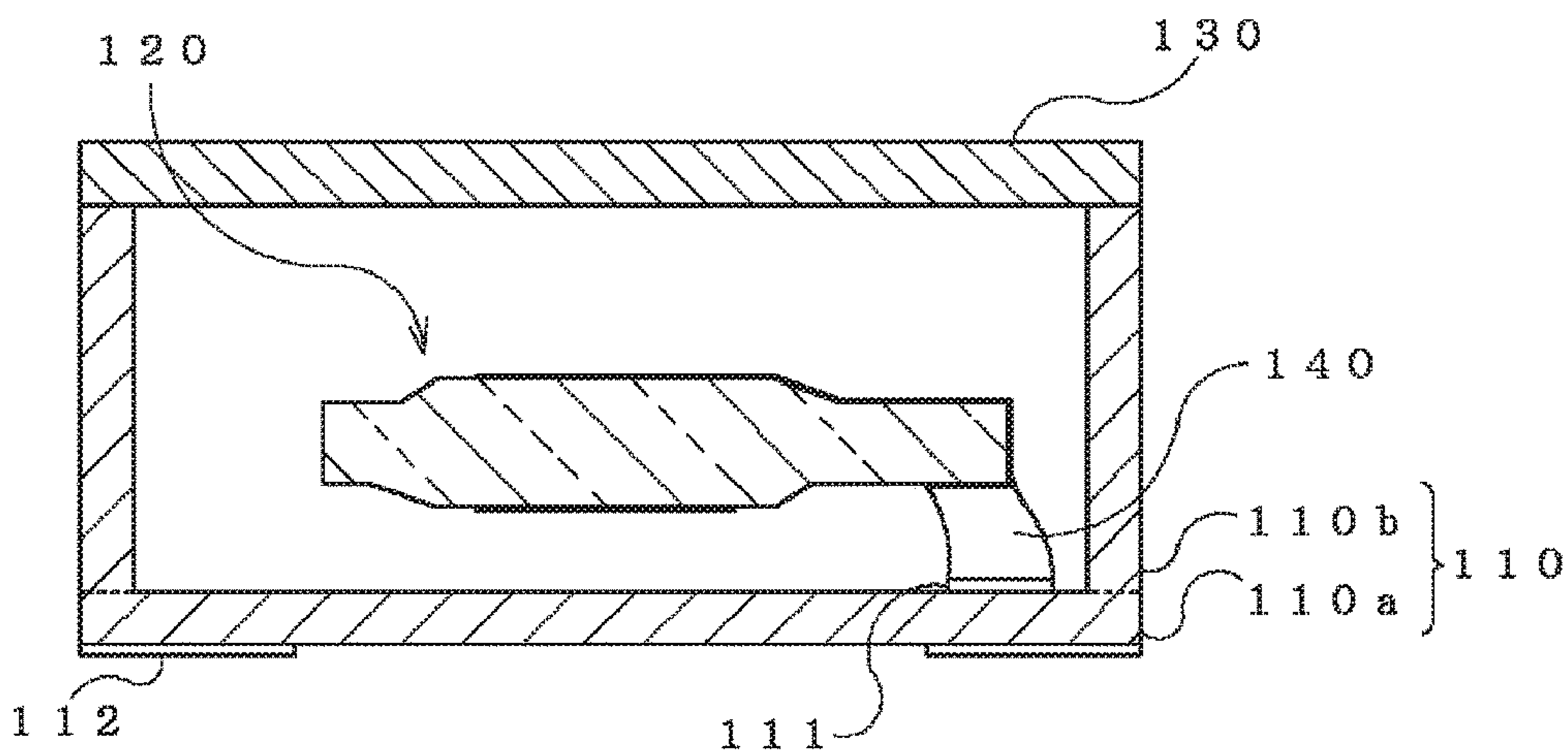


FIG.3A

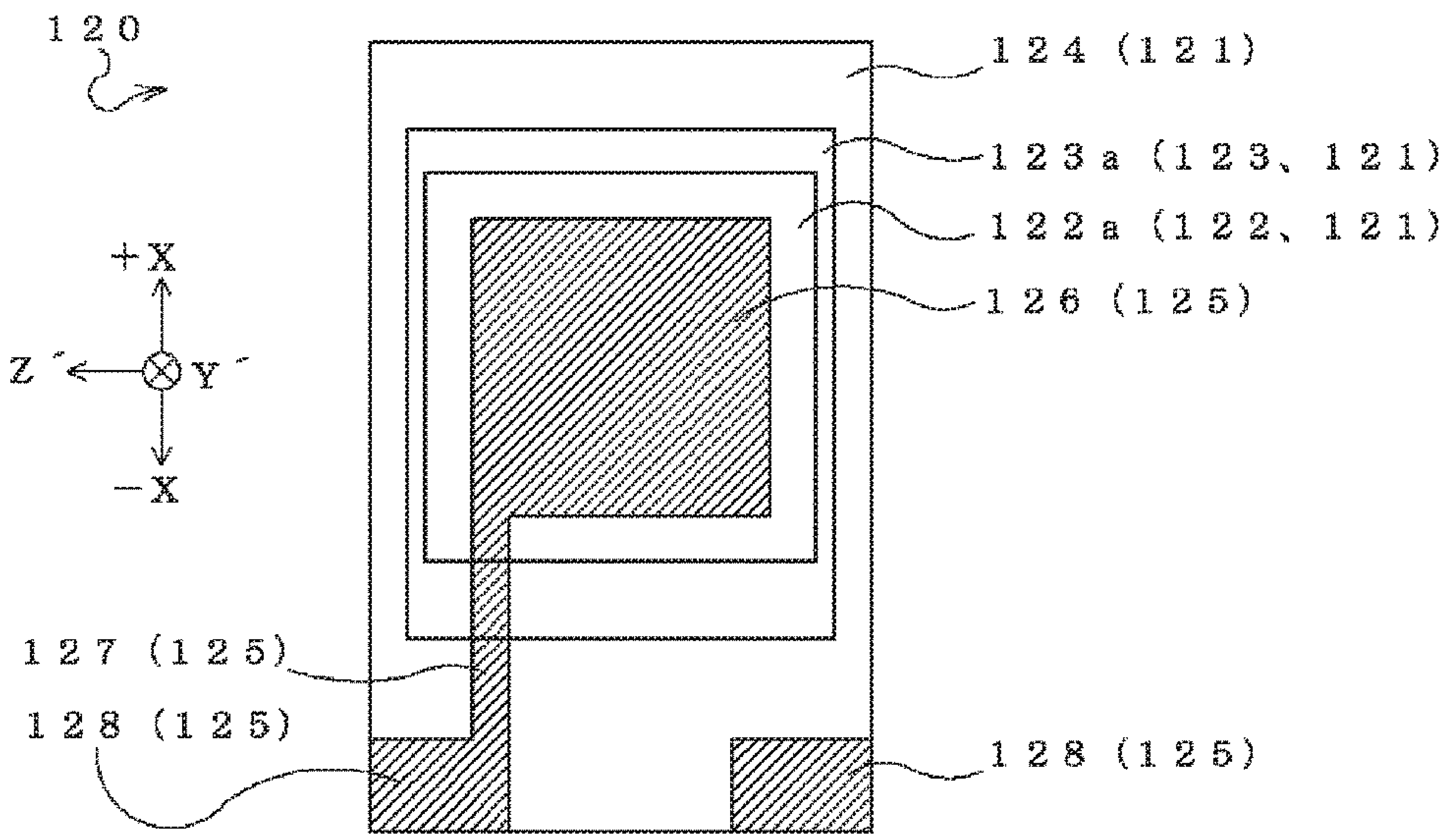

120
124 (121)
123a (123、121)
122a (122、121)
126 (125)
+X
Z´
Y´
−X
127 (125)
128 (125)
128 (125)

FIG.3B

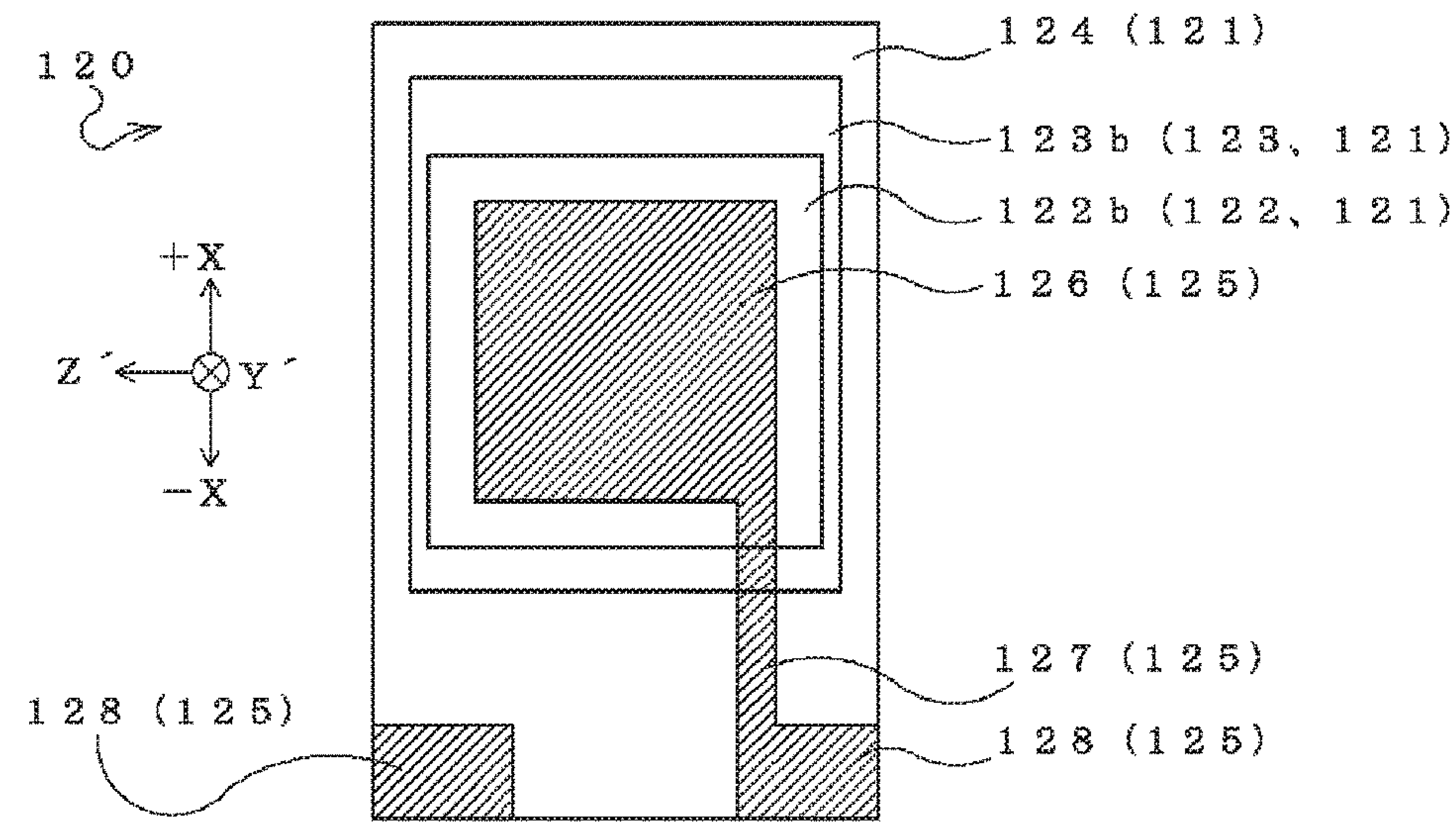

120
124 (121)
123b (123、121)
122b (122、121)
126 (125)
+X
Z´
Y´
−X
127 (125)
128 (125)
128 (125)

FIG.4A

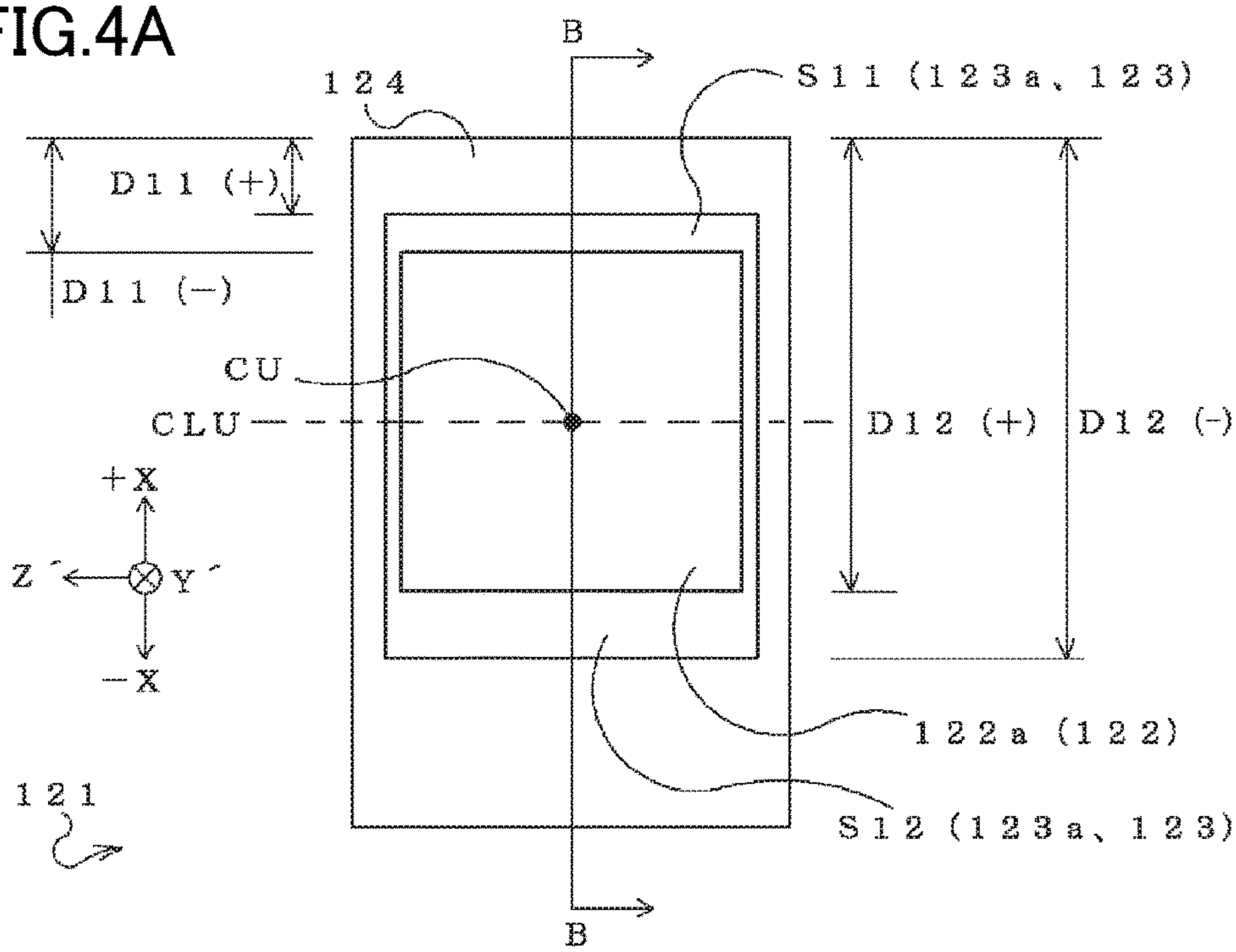

B
124
S11 (123a、123)
D11 (+)
D11 (−)
CU
CLU
D12 (+)
D12 (-)
+X
Z′
Y′
−X
122a (122)
121
S12 (123a、123)
B

FIG.4B

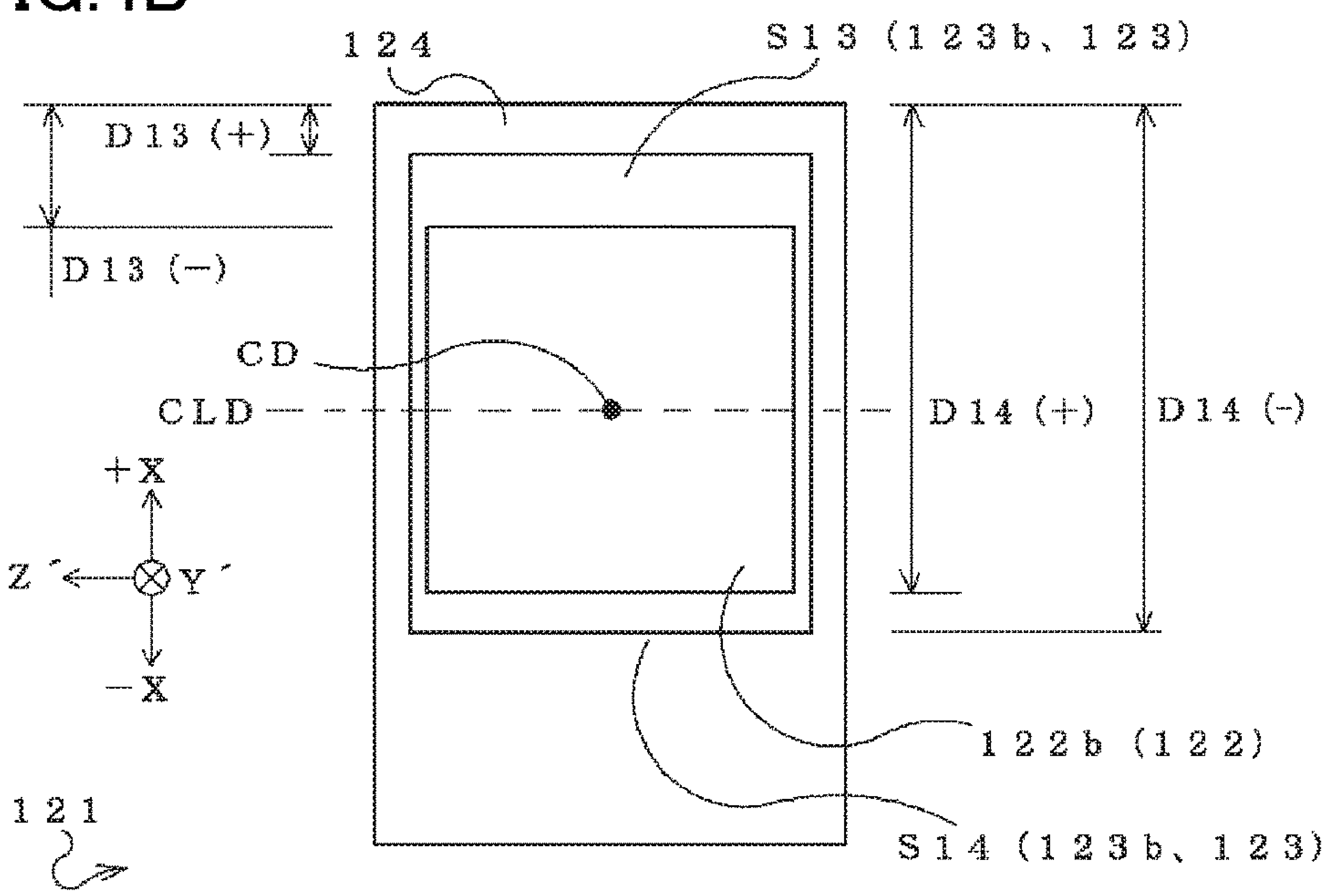

124
S13 (123b、123)
D13 (+)
D13 (−)
CD
CLD
D14 (+)
D14 (-)
+X
Z′
Y′
−X
122b (122)
121
S14 (123b、123)

FIG.5

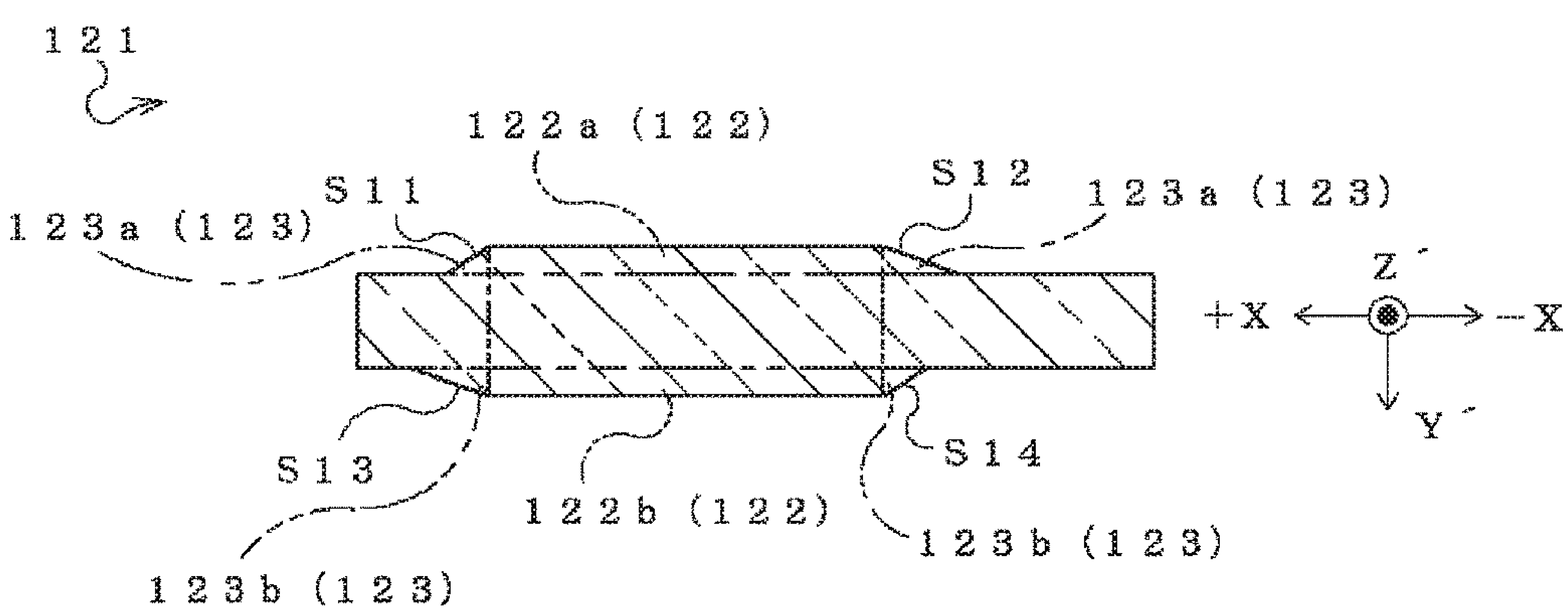
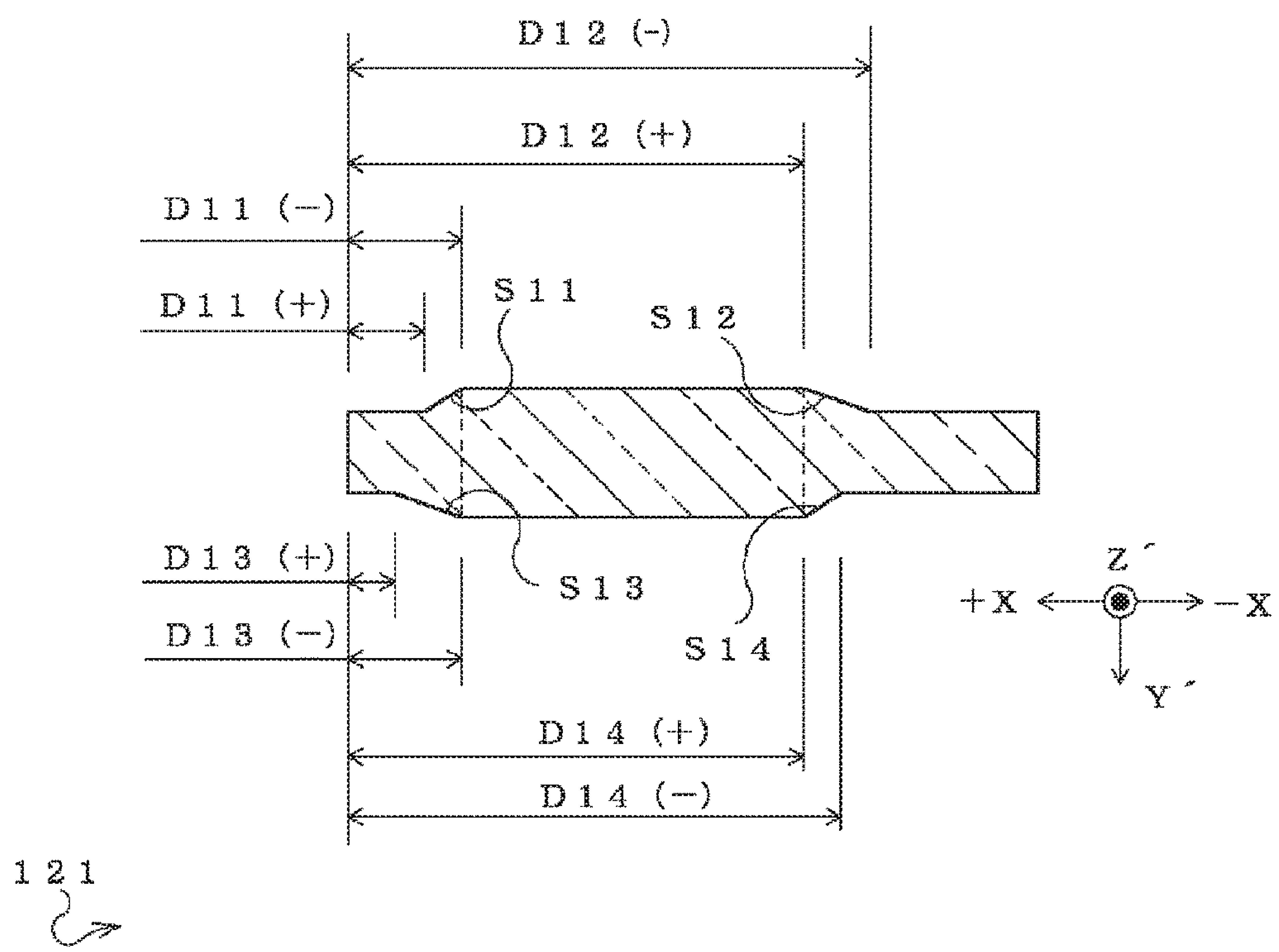

121
122a (122)
S11
S12
123a (123)
123a (123)
Z
+X
-X
Y
S13
S14
122b (122)
123b (123)
123b (123)

FIG.6



CRYSTAL ELEMENT AND CRYSTAL DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a crystal element and a crystal device that is provided with the crystal element. The crystal device is a crystal vibrator or a crystal oscillator, for example.

2. Description of the Related Art

The crystal element is configured with a crystal piece that is a mesa type and in a substantially rectangular shape in a plan view and a metal pattern provided on the crystal piece, for example. The metal pattern is configured with a pair of excitation electrodes, a pair of leading sections, and a pair of wiring sections. The pair of excitation electrodes is provided on both main surfaces of the crystal piece. The pair of leading sections is for mounting the crystal element to an element loading member, and disposed in opposition to a loading pad of the element loading member. One end of the pair of wiring sections is connected to the excitation electrodes, and the other end thereof is connected to the leading sections. Through electrically connecting the leading section and the loading pad of the element loading member via a conductive adhesive, the crystal element is supported like a cantilever beam and mounted to the element loading member.

The crystal piece used for such crystal element includes, for example, an oscillation section containing a pair of protrusions projected to mutually opposing directions, and a peripheral section that is thinner than the thickness of the oscillation section and provided along an outer edge of the oscillation section. In this case, the long side of the crystal piece is in parallel to the X-axis that is one of the crystalline axes of the crystal piece. Meanwhile, the short side of the crystal piece is in parallel to the Z'-axis that is rotated from the Z-axis that is one of the crystalline axes of the crystal piece. One of the protrusions includes a side face sloping with respect to the main surface of the protrusion itself and a side face perpendicular to the main surface of the protrusion itself in a sectional view taken along the thickness direction of the crystal piece facing in the direction in parallel to the Z'-axis. The other protrusion includes a side face sloping with respect to the main surface of the other protrusion itself and a side face sloping with respect to the main surface of the other protrusion itself in a sectional view taken along the thickness direction of the crystal piece facing in the direction in parallel to the Z'-axis. In a plan view taken along the thickness direction, the crystal pieces are disposed in such a manner that the side face sloping with respect to the main surface of one of the protrusions overlap with the side face perpendicular to the main surface of the other protrusion while the side face perpendicular to the main surface of one of the protrusions overlaps with the side face perpendicular to the main surface of the other protrusion (e.g., see Japanese Unexamined Patent Publication No. 2013-197621 (Patent Document 1)).

Such crystal element is so structured that a part of the crystal piece sandwiched between the pair of excitation electrodes oscillates when an alternate voltage is applied to the metal pattern. In that case, the oscillation of the crystal piece sandwiched between the pair of excitation electrodes propagates from the outer edge of the excitation electrodes toward the outer edge of the crystal pieces in a plan view, i.e., in the direction toward the side face of the protrusion. When the oscillation propagates to the outer edge of the crystal piece, specifically to the side face of the protrusion, the oscillation is reflected at the side face of the protrusion. The conventional crystal element uses the crystal piece that includes the protrusion having the side face perpendicular to the main surface of the protrusion itself and the other protrusion having the side face perpendicular to the main surface of the other protrusion itself, and the excitation electrodes are provided on the both main surfaces of the crystal piece, i.e., on the main surface of the protrusion and the main surface of the other protrusion. Thus, the reflection amount of the oscillation propagated from a part of the crystal piece sandwiched between the pair of excitation electrodes becomes greater in the side face that is perpendicular to the main surface of the protrusion compared to that of the side face sloping with respect to the main surface of the protrusion. Therefore, the oscillation of a part of the crystal piece sandwiched between the excitation electrodes and the reflected oscillation are combined. As a result, the equivalent series resistance value becomes increased so that the electric characteristic may be deteriorated.

It is an exemplary object of the present invention to provide a crystal element and a crystal device capable of decreasing changes in the electric characteristics caused when the oscillation propagated from a part of the crystal piece sandwiched between the excitation electrodes is reflected at the side face of the protrusion.

SUMMARY OF THE INVENTION

In order to overcome the foregoing issue, the crystal element according to the present invention is a crystal element which includes: a crystal piece in a substantially rectangular shape in a plan view, which includes an oscillation section having a first protruded section and a second protruded section projected to mutually opposing directions and a peripheral section which is thinner than the oscillation section and provided along an outer edge of the oscillation section; a pair of excitation electrodes provided on a top surface of the first protruded section and on a bottom surface of the second protruded section; a pair of leading sections provided side by side along a prescribed side of the crystal piece; and a wiring section whose one end is connected to the excitation electrode and other end is connected to the leading section, wherein: the first protruded section includes a first side face that is sloping with respect to the top surface of the first protruded section where the excitation electrode is provided, and a second side face which is opposing to the first side face in a prescribed direction and opposing to the top surface of the first protruded section where the excitation electrode is provided; the second protruded section includes a third side face that is sloping with respect to the bottom surface of the second protruded section where the excitation electrode is provided, and a fourth side face which is opposing to the third side face in a prescribed direction and opposing to the bottom surface of the second protruded section where the excitation electrode is provided; the first side face is disposed to overlap with the third side face in a plan view of the crystal piece in a thickness direction; and the second side face is disposed to overlap with the fourth side face in the plan view of the crystal piece in the thickness direction.

The crystal element according to the present invention is a crystal element which includes: a crystal piece in a substantially rectangular shape in a plan view, which includes an oscillation section having a first protruded section and a second protruded section projected to mutually opposing directions and a peripheral section which is thinner than the oscillation section and provided along an outer edge of the oscillation section; a pair of excitation electrodes provided on a top surface of the first protruded section and on a bottom surface of the second protruded section; a pair of leading sections provided side by side along a prescribed side of the crystal piece; and a wiring section whose one end is connected to the excitation electrode and other end is connected to the leading section, wherein: the first protruded section includes a first side face that is sloping with respect to the top surface of the first protruded section where the excitation electrode is provided, and a second side face which is opposing to the first side face in a prescribed direction and opposing to the top surface of the first protruded section where the excitation electrode is provided; the second protruded section includes a third side face that is sloping with respect to the bottom surface of the second protruded section where the excitation electrode is provided, and a fourth side face which is opposing to the third side face in a prescribed direction and opposing to the bottom surface of the second protruded section where the excitation electrode is provided; the first side face is disposed to overlap with the third side face in a plan view of the crystal piece in a thickness direction; and the second side face is disposed to overlap with the fourth side face in the plan view of the crystal piece in the thickness direction. Thus, the first side face and the second side face are sloping with respect to the top surface of the first protruded section, while the third side face and the fourth side face are sloping with respect to the bottom surface of the second protruded section. Therefore, the crystal element according to the present invention is capable of decreasing the amount of the oscillation propagated from the part sandwiched between the excitation electrodes and reflected at the first side face, the second side face, the third side face, and the fourth side face compared to the case where the first side face or the second side face is perpendicular to the top surface of the first protruded section and the case where the third side face or the fourth side face is perpendicular to the bottom surface of the second protruded section. As a result, the deterioration amount of the electric characteristic caused by the oscillation reflected at the first side face, the second side face, the third side face, and the fourth side face can be suppressed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a crystal device according to an exemplary embodiment;

FIG. **2** is a sectional view taken along a line A-A of FIG. **1**;

FIG. **3**A is a plan view of the top surface of a crystal element according to the exemplary embodiment;

FIG. **3**B is a perspective plan view of the bottom surface of the crystal element according to the exemplary embodiment viewed from the top surface;

FIG. **4**A is a plan view of the top surface of a crystal piece;

FIG. **4**B is a perspective plan view of the bottom surface of the crystal piece viewed from the top surface;

FIG. **5** is a sectional view taken along a line B-B of FIG. **4**A for describing the angles between the main surfaces and side faces of protrusions; and

FIG. **6** is a sectional view taken along the line B-B of FIG. **4**A for describing the distance from a prescribed other side of the crystal piece to the side faces.

DETAILED DESCRIPTIONS OF THE PREFERRED EXEMPLARY EMBODIMENTS

FIG. **1** is a perspective view of a crystal device according to an exemplary embodiment, and FIG. **2** is a sectional view taken along a line A-A of FIG. **1**. FIG. **3**A and FIG. **3**B are plan views of a crystal element **120** according to the exemplary embodiment. FIG. **4**A and FIG. **4**B are plan views of a crystal piece **121**. FIG. **5** and FIG. **6** are sectional views of the crystal piece **121** taken along a line B-B.

(Schematic Structure of Crystal Device)

The crystal device is an electronic component that is in a substantially cuboid shape as a whole, for example. The length of the long side or the short side of the crystal device is 0.6 mm to 2.0 mm, and the thickness thereof in the vertical directions is 0.2 mm to 1.5 mm.

For example, the crystal device is configured with: an element loading member **110** where a recessed section is formed; a crystal element **120** housed inside the recessed section; a lid **130** for covering the recessed section; and a conductive adhesive **140** for adhesively mounting the crystal element **120** to the element loading member **110**.

The recessed section of the element loading member **110** is sealed by the lid **130**, and the inside thereof is in a vacuum, for example, or an appropriate gas (e.g., nitrogen) is enclosed therein.

For example, the element loading member **110** is configured with: a base unit **110*a*** to be the main body of the element loading member **110**; a frame unit **110*b*** provided along the edge of the top surface of the base unit **110*a***; a loading pad **111** for mounting the crystal element **120**; and an external terminal **112** for mounting the crystal device to a circuit board and the like, not shown. The frame-shaped frame unit **110*b*** is provided to the element loading member **110** along the edge of the top surface of the base unit **110*a***, thereby forming the recessed section.

The base unit **110*a*** and the frame unit **110*b*** are formed with an insulating material such as a ceramic material. The loading pad **111** and the external terminal **112** are formed with a conductive layer made of metal or the like, for example, and are electrically connected to each other via a conductor (not shown) disposed inside the base unit **110*a***. The lid **130** is formed with metal, for example, and joined to the element loading member **110**, specifically to the top surface of the frame unit **110*b*** by seam welding or the like.

The crystal element **120** includes, for example: a pair of excitation electrodes **126** for applying a voltage to the crystal piece **121**; and a pair of wiring sections **127** for mounting the crystal element **120** to the loading pad **111**.

The crystal piece **121** is the so-called AT-cut crystal piece. That is, it is a plate cut out in parallel to the XZ' plane when the Cartesian coordinates XYZ formed with the X-axis (electrical axis), the Y-axis (mechanical axis), and the Z-axis (optical axis) in a crystal is rotated about the X-axis at an angle in a range of 30° to 50°, both inclusive, (35° 15', for example) to define the Cartesian coordinates system XY'Z'.

The pair of excitation electrodes **126** and the pair of wiring sections **127** are formed with a conductor made of metal. The pair of excitation electrodes **126** is provided on the center side of the both main surfaces of the crystal piece **121**, for example. The pair of wiring sections **127** are extended from the excitation electrodes **126** toward the one side of the X-axis direction (e.g., −X direction side), and include a pair of leading sections **128** along the end part of a prescribed side of the crystal piece **121**.

The crystal element **120** is housed inside the recessed section of the element loading member **110** by having the main surface thereof facing the top surface of the base unit **110*a*** of the element loading member **110**. The leading sections **128** are adhesively fixed to the loading pad **111** provided to the base unit **110*a*** of the element loading member **110** via the conductive adhesive **140**. Thereby, the crystal element **120** is supported by the element loading member **110** like cantilever beam. Further, the pair of excitation electrodes **126** are electrically connected to a pair of loading pads **111** of the element loading member **110** and electrically connected to two external terminals out of a plurality of external terminals **112** of the element loading member **110** consequently.

The crystal device structured in this manner is disposed by having the bottom face of the element loading member opposed to the mounting face of the circuit board, not shown, for example, and mounted to the circuit board through joining the external terminals **112** to the pad of the circuit board by soldering or the like. For example, an oscillation circuit is structured on the circuit board. The oscillation circuit generates oscillation signals by applying alternate voltages to the pair of excitation electrodes **126** via the external terminals **112** and the loading pads **111**. At this time, the oscillation circuit utilizes a basic wave vibration among the thickness slip vibration of the crystal piece **121**, for example.

(Shape of Crystal Element)

FIG. **3**A is a plan view of the top surface of the crystal element **120** viewed two-dimensionally, and FIG. **3**B is a perspective plan view of the bottom surface of the crystal element **120** viewed from the top surface. Further, FIG. **4**A is a plan view of the top surface of the crystal piece viewed two-dimensionally, and FIG. **4**B is a perspective plan view of the bottom surface of the crystal piece **121** viewed from the top surface. FIG. **5** and FIG. **6** are sectional views taken along a line B-B.

The exemplary embodiment is described assuming that the face substantially in parallel to the top surface of the base unit **110***a* of the element loading member **110** is the main surface when the crystal element **120** is mounted to the element loading member **110**, the direction from the crystal element **120** toward the base unit **110***a* of the element loading member **110** is the downward direction, and the direction from the base unit **110***a* of the element loading member **110** toward the crystal element **120** is the upward direction.

The surface of the crystal element **120** facing toward the base unit **110***a* of the element loading member **110***a* is defined as the bottom face of the crystal element **120**, the surface of the crystal element **120** facing toward the opposite side of the bottom face of the crystal element **120** is defined as the top surface of the crystal element **120**, and the top surface of the crystal element **120** and the bottom surface of the crystal element **120** are defined as the main surfaces of the crystal element **120**. Similarly, the surface of the crystal piece **121** facing toward the base unit **110***a* of the element loading member **110** is defined as the bottom face of the crystal piece **121**, the surface of the crystal piece **121** facing toward the opposite side of the bottom face of the crystal piece **121** is defined as the top surface of the crystal piece **121**, and the top surface of the crystal piece **121** and the bottom surface of the crystal piece **121** are defined as the main surfaces of the crystal piece **121**. Similarly, the surface of the oscillation section **122** facing toward the base unit **110***a* of the element loading member **110** is defined as the bottom face of the oscillation section **122**, the surface of the oscillation section **122** facing toward the opposite side of the bottom face of the oscillation section **122** is defined as the top surface of the oscillation section **122**, and the top surface of the oscillation section **122** and the bottom surface of the oscillation section **122** are defined as the main surfaces of the oscillation section **122**.

Further, the protrusion provided to the oscillation section **122** and projected toward the opposite side of the base unit **110***a* of the element loading member **110** is defined as a first protruded section **122***a*, and the protrusion projected toward the base unit **110***a* side of the element loading member **110** is defined as a second protruded section **122***b*. In this case, the surface of the first protruded section **122***a* substantially in parallel to the top surface of the base unit **110***a* of the element loading member **110** is defined as the main surface of the first protruded section **122***a*, and the surface of the second protruded section **122***b* substantially in parallel to the top surface of the base unit **110***a* of the element loading member **110** is defined as the main surface of the second protruded section **122***b*.

Note that the top surface of the oscillation section **122** and the main surface of the first protruded section **122***a* are used as the same meaning, and the top surface of the crystal element **120** and the top surface of the crystal piece **121** are used as the same meaning. Further, the top surface of the crystal element **120**, the top surface of the crystal piece **121**, the top surface of the oscillation section **122**, and the main surface of the first protruded section **122***a* are located on a same plane. Meanwhile, the bottom surface of the oscillation section **122** and the main surface of the second protruded section **122***b* are used as the same meaning, and the bottom surface of the crystal element **120** and the bottom surface of the crystal piece **121** are used as the same meaning. Further, the bottom surface of the crystal element **120**, the bottom surface of the crystal piece **121**, the bottom surface of the oscillation section **122**, and the main surface of the second protruded section **122***b* are located on a same plane.

The crystal element **120** is configured with: the crystal piece **121** including the first protruded section **122***a* and the second protruded section **122***b*; the excitation electrodes **126**; and the metal pattern **125** constituted with the wiring sections **127** and the leading sections **128**.

The crystal piece **121** is the so-called mesa type, which is configured with the oscillation section including the first protruded section **122***a* and the second protruded section **122***b* projected toward the directions opposing to each other, sloping sections **123**, and a peripheral section **124**. Such shape makes it possible to improve the energy enclosing effect compared to a case of using a plate-type crystal piece and the equivalent series resistance value can be made smaller as a result. The shape of the crystal piece **121** in a plan view is a substantially rectangular shape. The main surface thereof is a rectangular including the long sides that are in parallel to the X-axis and the short sides that are in parallel to the Z'-axis. In such crystal piece **121**, the X-axis direction is defined as the longitudinal direction.

The oscillation section **122** is a thin-type cuboid having a pair of main surfaces in parallel to the XZ' plane, for example, and the main surfaces thereof are rectangles having the long sides in parallel to the X-axis and short sides in parallel to the Z'-axis. A pair of excitation electrodes **126** is provided to the both main surfaces (the main surface of the first protruded section **122***a* and the main surface of the second protruded section **122***b*) of the oscillation section **122**. When an alternate voltage is applied to the pair of excitation electrodes **126**, a part of the oscillation section **122** sandwiched between the excitation electrodes **126** can be thickness-slip-vibrated due to an inverted piezoelectric effect or a piezoelectric effect. At this time, the thickness slip vibration is propagated from the part sandwiched between the excitation electrodes **126** also to the outer edge side of the oscillation section **122** that is not sandwiched between the excitation electrodes **126**.

As described above, in the exemplary embodiment, the protrusion provided to the oscillation section **122** and projected toward the opposite side of the base unit **110***a* of the element loading member **110** is defined as the first protruded section **122***a*, and the protrusion projected toward the base unit **110***a* side of the element loading member **110** is defined as the second protruded section **122***b*.

The first protruded section **122***a* is the protrusion projected upward. As shown in FIG. **3**A, the first protruded section **122***a* is in a rectangular shape having the long sides that are in parallel to the X-axis and the short sides that are in parallel to the Z'-axis in a plan view of the top surface of the crystal piece **121**. Further, the sloping section **123** (the first slope **123***a*) is provided along the outer edge of the first protruded section **122***a*.

The second protruded section **122***b* is the protrusion projected downward. As shown in FIG. **3**B, the second protruded section **122***b* is in a rectangular shape having the long sides that are in parallel to the X-axis and the short sides that are in parallel to the Z'-axis in a perspective plan view of the bottom surface of the crystal piece **121** viewed from the top surface. Also, the main surface of the second protruded section **122***b* is in parallel to the main surface of the first protruded section **122***a* as shown in FIGS.A **4**A and **4**B. Further, the sloping section **123** (the second slope **123***b*) is provided along the outer edge of the second protruded section **122***b*.

The sloping section **123** includes the first slope **123***a* and the second slope **123***b*. The thickness in the vertical direction of the sloping section **123** becomes gradually thinner from the oscillation section **122** toward the direction of the peripheral unit **124** in a sectional view of the crystal piece **121** as shown in FIG. **5** and FIG. **6**. The first slope **123***a* is a part of the sloping section **123** provided along the outer edge of the first protruded section **122***a*. The second slope **123***b* is a part of the sloping section **123** provided along the outer edge of the second protruded section **122***b*.

Here, as shown in FIG. **5**, the side face that is the first slope **123***a* (the sloping section **123** provided along the first protruded section **122***a*) and located in the +X-axis direction is defined as a first side face **S11** in a sectional view of the crystal piece **121** taken along the XY' plane (the face in parallel to the X-axis and the Y'-axis), and the side face that is the first slope **123***a* and located in −X-axis direction is defined as a second side face **S12**. Further, as shown in FIG. **4**A and FIG. **5**, the side face that is the second slope **123***b* (the sloping section **123** provided along the second protruded section **122***b*) and located in the +X-axis direction is defined as a third side face **S13** in a sectional view of the crystal piece **121** taken along the XY' plane, and the side face that is the second slope **123***b* and located in −X-axis direction is defined as a fourth side face **S14**.

As shown in FIG. **5**, the first side face **S11** is a surface located on the +X-axis side among the surfaces of the slope **123***a* in parallel to the Z'-axis in a plan view of the top surface of the crystal piece **121**. That is; the first side face **S11** is located on the positive direction side of the X-axis with respect to a virtual line CLU that is perpendicular to the X-axis passing through the center CU of the main surface (the top surface of the oscillation section **122**) of the first protruded section **122***a*. The angle between the first side face **S11** and the main surface of the first protruded section **122***a* is an obtuse angle (an angle larger than 90° and smaller than 180°). Specifically, it is 135° to 155°.

As shown in FIG. **5**, the second side face **S12** is a surface located on the −X-axis side among the surfaces of the slope **123***a* in parallel to the Z'-axis in a plan view of the top surface of the crystal piece **121**. That is, the second side face **S12** is located on the negative direction side of the X-axis with respect to the virtual line CLU that is perpendicular to the X-axis passing through the center CU of the main surface (the top surface of the oscillation section **122**) of the first protruded section **122***a*. The angle between the second side face **S12** and the main surface of the first protruded section **122***a* is an obtuse angle (an angle larger than 90° and smaller than 180°). Specifically, it is 150° to 170°.

As shown in FIG. **5**, the third side face **S13** is a surface located on the +X-axis side among the surfaces of the second slope **123***b* in parallel to the Z'-axis in a perspective plan view of the bottom surface of the crystal piece **121** viewed from the top surface thereof. That is, the third side face **S13** is located on the positive direction side of the X-axis with respect to the virtual line CLU that is perpendicular to the X-axis passing through the center CU of the main surface (the bottom surface of the oscillation section **122**) of the second protruded section **122***b*. The angle between the third side face **S13** and the main surface of the second protruded section **122***b* is an obtuse angle (an angle larger than 90° and smaller than 180°). Specifically, it is 150° to 170°. Further, as shown in FIG. **5** and FIG. **6**, in the sectional view of the crystal piece **121** taken along the XY' plane (the surface in parallel to the X-axis and the Y'-axis), the third side face **S13** is located at the position overlapping with the first side face **S11** vertically.

As shown in FIG. **5**, the fourth side face **S14** is a surface located on the −X-axis side among the surfaces of the second slope **123***b* in parallel to the Z'-axis in a perspective plan view of the bottom surface of the crystal piece **121** viewed from the top surface thereof. That is, the fourth side face **S14** is located on the negative direction side of the X-axis with respect to the virtual line CLU that is perpendicular to the X-axis passing through the center CU of the main surface (the bottom surface of the oscillation section **122**) of the second protruded section **122***b*. The angle between the fourth side face **S14** and the main surface of the second protruded section **122***b* is an obtuse angle (an angle larger than 90° and smaller than 180°). Specifically, it is 135° to 155°. Further, as shown in FIG. **5** and FIG. **6**, in the sectional view of the crystal piece **121** taken along the XY' plane (the surface in parallel to the X-axis and the Y'-axis), the fourth side face **S14** is located at the position overlapping with the second side face **S12** vertically.

Therefore, as shown in FIG. **5** and FIG. **6**, in the sectional view of the crystal piece **121**, the first side face **S11** and the third side face **S13** are located in the vertical direction while the second side dace **S12** and the fourth side face **S14** are located in the vertical direction. From another view point, in the perspective plan view of the crystal piece **121**, the first side face **S11** and the third side face **13** overlap with each other while the second side face **S12** and the fourth side face **S14** overlap with each other. With such structure, in a case where oscillation is propagated from the part sandwiched between the excitation electrodes **126** toward the direction from the outer edge of the excitation electrodes **126** to the outer edge of the oscillation section **122** in the plan view of the crystal element **120**, the angle between the propagating direction and the side face (the first side face **S11**, the second side face **S12**, the third side face **S13**, or the fourth side face **S14**) can be made smaller compared to the case where the side face (the first side face **S11**, the second side face **S12**, the third side face **S13**, or the fourth side face **S14**) is perpendicular. Therefore, the amount reflected at the first side face **S11**, the second side face **S12**, the third side face **S13**, and the fourth side face **S14** can be decreased, so that the deterioration amount of the electric characteristic caused by the oscillation reflected at the first side face **S11**, the second side face **S12**, the third side face **S13**, and the fourth side face **S14** can be suppressed.

Further, in the crystal piece **121**, the first side face **S11** and the third side face **S13** are located in the vertical direction while the second side dace **S12** and the fourth side face **S14** are located in the vertical direction in the sectional view taken along the XY' plane (the surface in parallel to the X-axis and the Y'-axis). That is, in the plan view of the crystal piece **121**, the first side face **S11** is located on the positive direction side of the X-axis with respect to the virtual line CLU which passes the center CU of the main surface of the first protruded section **122***a* and is perpendicular to the X-axis, the second side face **S12** is located on the negative direction side of the X-axis with respect to the virtual line CLU which passes the center CU of the main surface of the first protruded section **122***a* and is perpendicular to the X-axis, the third side face **S13** is located on the positive direction side of the X-axis with respect to the virtual line CLU which passes the center CU of the main surface of the second protruded section **122***b* and is perpendicular to the X-axis, and the fourth side face **S14** is located on the negative direction side of the X-axis with respect to the virtual line CLU which passes the center CU of the main surface of the second protruded section **122***b* and is perpendicular to the X-axis. With this, oscillation reflected at the side face (the first side face **S11**, the second side face **S12**, the third side face **S13**, or the fourth side face **S14**) can be decreased, so that the influence imposed upon the thickness slip vibration of the part sandwiched between the excitation electrodes **126** can be suppressed. Therefore, the deterioration amount of the electric characteristic can be suppressed. In general, when a voltage is applied to the excitation electrodes **126** and a part of the oscillation section **122** sandwiched between the excitation electrodes **126** is thickness-slip-vibrated, the vibration displacement becomes the greatest in the center part in the direction in parallel to the X-axis. Thus, the oscillation reflected and propagated from the side face in a direction in parallel to the X-axis tends to influence the thickness slip vibration of the part sandwiched between the excitation electrodes **126**. That is, the exemplary embodiment is designed to locate the first side face **S11** and the third side face **S13** in the vertical direction and locate the second side dace **S12** and the fourth side face **S14** in the vertical direction in the sectional view taken along the XY' plane (the surface in parallel to the X-axis and the Y'-axis) so that the oscillation reflected at the side face (the first side face **S11**, the second side face **S12**, the third side face **S13**, or the fourth side face **S14**) can be more decreased compared to the case where those are located in the vertical direction in the sectional view of the Z'Y' plane. Thus makes it possible to decrease the influence imposed upon the thickness slip vibration of the part sandwiched between the excitation electrodes **126**, so that the deterioration amount of the electric characteristic can be suppressed.

Further, in the crystal piece **121** of the exemplary embodiment, the angle between the main surface of the first protruded section **122***a* and the first side face **S11** is an obtuse angle (an angle larger than 90° and smaller than 180°) in the sectional view taken along the XY' plane (the surface in parallel to the X-axis and the Y'-axis), the angle between the main surface of the first protruded section **122***a* and the second side face **S12** is an obtuse angle, the angle between the main surface of the second protruded section **122***b* and the third side face **S13** is an obtuse angle, and the angle between the main surface of the second protruded section **122***b* and the fourth side face **S14** is an obtuse angle. With such structure, in a case where oscillation is propagated from the part sandwiched between the excitation electrodes **126** toward the direction from the outer edge of the excitation electrodes **126** to the outer edge of the oscillation section **122** in the plan view of the crystal element **120**, the angle between the propagating direction and the side face (the first side face **S11**, the second side face **S12**, the third side face **S13**, or the fourth side face **S14**) can be made still smaller compared to the case where the side face (the first side face **S11**, the second side face **S12**, the third side face **S13**, or the fourth side face **S14**) is perpendicular. Therefore, the amount reflected at the first side face **S11**, the second side face **S12**, the third side face **S13**, and the fourth side face **S14** can be decreased, so that the deterioration amount of the electric characteristic caused by the oscillation reflected at the first side face **S11**, the second side face **S12**, the third side face **S13**, and the fourth side face **S14** can be suppressed further.

Specifically, in the crystal piece **121** of the exemplary embodiment, the angle between the main surface of the first protruded section **122***a* and the first side face **S11** is 135° to 155°, the angle between the main surface of the first protruded section **122***a* and the second side face **S12** is 150° to 170°, the angle between the main surface of the second protruded section **122***b* and the third side face **S13** is 150° to 170°, and the angle between the main surface of the second protruded section **122***b* and the fourth side face **S14** is 135° to 155°. With such structure, when a voltage is applied to the excitation electrodes **126** and a part of the oscillation section **122** sandwiched between the excitation electrodes **126** is thickness-slip-vibrated, the amount of oscillation reflected at the side face (the first side face **S11**, the second side face **S12**, the third side face **S13**, or the fourth side face **S14**) to the direction in parallel to the X-axis can be more decreased, so that the deterioration amount of the electric characteristic can be suppressed further. Especially, the angles with respect to the side faces and the way of propagation of the thickness slip vibration are determined according to the cut angles of the crystal wafer, so that the deterioration amount of the electric characteristic is suppressed by determining the angles with respect to the side faces in this manner in the exemplary embodiment. Note that the tolerance of the angles is within ±3°.

In the plan view of the crystal piece **121**, the peripheral section **124** is provided along the outer edge of the sloping unit **123**. The thickness of the peripheral section **124** in the vertical direction is thinner than the thickness of the oscillation section **122** in the vertical direction (the distance from the main surface of the first protruded section **122***a* to the main surface of the second protruded section **122***b*).

As shown in FIG. **4**A, in the plan view of the top surface of the crystal piece **121**, distance D**11** (+) from a prescribed other side of the crystal piece **121** (the side opposing to a prescribed side of the crystal piece **121** where the leading sections **128** are provided side by side) to the first side face **S11** located on the positive direction side of the X-axis is shorter than distance D**11** (−) from the prescribed other side of the crystal piece **121** to the first side face **S11** located on the negative direction side of the X-axis. Further, distance D**12** (+) from a prescribed other side of the crystal piece **121** to the second side face **S12** located on the positive direction side of the X-axis is shorter than distance D**12** (−) from the prescribed other side of the crystal piece **121** to the second side face **S12** located on the negative direction side of the X-axis.

As shown in FIG. **4**B, in the perspective plan view of the bottom surface of the crystal piece **121** viewed through the top surface, distance D**13** (+) from a prescribed other side of the crystal piece **121** to the third side face S**13** located on the positive direction side of the X-axis is shorter than distance D**13** (−) from the prescribed other side of the crystal piece **121** to the third side face S**13** located on the negative direction side of the X-axis. Further, distance D**14** (+) from a prescribed other side of the crystal piece **121** to the fourth side face S**14** located on the positive direction side of the X-axis is shorter than distance D**14** (−) from the prescribed other side of the crystal piece **121** to the fourth side face S**14** located on the negative direction side of the X-axis.

As shown in FIG. **4**B and FIG. **6**, the distance D**13** (+) from the prescribed other side of the crystal piece **121** to the third side face S**13** located on the positive direction side of the X-axis is shorter than the distance D**11** (−) from the prescribed other side of the crystal piece **121** to the first side face S**11** located on the negative direction side of the X-axis. Further, as shown in FIG. **4**B and FIG. **6**, the distance D**14** (+) from the prescribed other side of the crystal piece **121** to the fourth side face S**14** located on the positive direction side of the X-axis is shorter than the distance D**12** (−) from the prescribed other side of the crystal piece **121** to the second side face S**12** located on the negative direction side of the X-axis. That is, in the crystal piece **121**, assuming that the side perpendicular to the X-axis located on the positive direction side of the X-axis with respect to the virtual lines CLU and CLD is the prescribed other side of the crystal piece **121**, the distance (D**13** (+)) from the prescribed other side to the side of the third side face S**13** close to the prescribed other side is shorter than the distance (D**11** (−)) from the prescribed other side to the side of the first side face S**11** distant from the prescribed other side, and the distance (D**14** (+)) from the prescribed other side to the side of the fourth side face S**14** close to the prescribed other side is shorter than the distance (D**12** (−)) from the prescribed other side to the side of the second side face S**12** distant from the prescribed other side

This makes it possible to locate the first side face S**11** and the third side face S**13** in the vertical direction while locating the second side face S**12** and the fourth side face S**14** in the vertical direction in the sectional view of the crystal piece **121**. From another view point, in the perspective plan view of the crystal piece **121**, the first side face S**11** and the third side face **13** can overlap with each other while the second side face S**12** and the fourth side face S**14** overlap with each other. That is, in a case where oscillation is propagated from the part sandwiched between the excitation electrodes **126** toward the direction from the outer edge of the excitation electrodes **126** to the outer edge of the oscillation section **122** in the plan view of the crystal element **120**, the angle between the propagating direction and the side face (the first side face S**11**, the second side face S**12**, the third side face S**13**, or the fourth side face S**14**) can be made smaller compared to the case where the side face (the first side face S**11**, the second side face S**12**, the third side face S**13**, or the fourth side face S**14**) is perpendicular. Therefore, the amount reflected at the first side face S**11**, the second side face S**12**, the third side face S**13**, and the fourth side face S**14** can be decreased, so that the deterioration amount of the electric characteristic caused by the oscillation reflected at the first side face S**11**, the second side face S**12**, the third side face S**13**, and the fourth side face S**14** can be suppressed.

In the crystal piece **121**, the distance D**11** (−) from the prescribed other side of the crystal piece **121** to the first side face S**11** located on the negative direction side of the X-axis and the distance D**13** (−) from the prescribed other side of the crystal piece **121** to the third side face S**13** located on the negative direction side of the X-axis are equivalent. That is, in the crystal piece **121**, the distance (D**11** (−)) from the prescribed other side to the side of the first side face S**11** distant from the prescribed other side is equivalent to the distance (D**13** (−)) from the prescribed other side to the side of the third side face S**13** distant from the prescribed other side, and the distance (D**14** (+)) from the prescribed other side to the side of the fourth side face S**14** close to the prescribed other side is equivalent to the distance (D**12** (+)) from the prescribed other side to the side of the second side face S**12** close to the prescribed other side. Further, in the crystal piece **121**, the distance D**12** (+) from the prescribed other side of the crystal piece **121** to the second side face S**12** located on the positive direction side of the X-axis and the distance D**14** (+) from the prescribed other side of the crystal piece **121** to the fourth side face S**14** located on the positive direction side of the X-axis are equivalent. With such structure, in the perspective plan view of the crystal piece **120**, the first side face S**11** located on the negative direction side of the X-axis and the third side face **13** located on the negative direction side of the X-axis can overlap with each other while the second side face S**12** located on the positive direction side of the X-axis and the fourth side face S**14** located on the positive direction side of the X-axis can overlap with each other. Therefore, the amount reflected at the first side face S**11**, the second side face S**12**, the third side face S**13**, and the fourth side face S**14** can be decreased. As a result, the deterioration amount of the electric characteristic caused by the oscillation reflected at the first side face S**11**, the second side face S**12**, the third side face S**13**, and the fourth side face S**14** can be suppressed.

Now, a method for forming such crystal piece **121** will be described. The forming method of such crystal piece **121** is constituted with a crystal wafer preparing step, a first etching step, and a second etching step, for example. In the crystal wafer preparing step, first, a crystal wafer having crystalline axes constituted with mutually orthogonal X-axis, Y-axis, and Z-axis is prepared. At this time, the thickness of the crystal wafer in the vertical direction is equivalent to the thickness of the oscillation section **122** in the vertical direction. Further, the cut angle of the main surface of the crystal wafer is equivalent to that of the main surface of the oscillation section **122**. Thus, the main surface of the crystal wafer is in parallel to the surface that is acquired by rotating the surface in parallel to the X-axis and the Z-axis about the X-axis at a prescribed angle counterclockwise to the negative direction of the X-axis. In the first etching step, a photolithography technique and an etching technique are used. First, a protection metal film is provided on the both main surfaces of the crystal wafer, a photosensitive resist is applied on the protection metal film, and it is exposed and developed to a prescribed pattern. At this time, in a plan view of the crystal wafer, the photosensitive resist remains in the part to be the oscillation section **122**, while no photosensitive resist remains in the part to be the sloping section **123** and the peripheral section **124**. Thereafter, the crystal wafer is soaked in a prescribed etching solution to be etched until the thickness of the etched crystal wafer in the vertical direction reaches the thickness of the peripheral section **124** in the vertical direction. At this time, the sloping section **123** is also formed by anisotropic etching that is peculiarly used for crystal. At last, the photosensitive resist and the protection metal film remained in the crystal wafer are exfoliated. In the second etching step, a protection metal film is provided on the both main surfaces of the crystal wafer that has gone through the first etching step, a photosensitive resist is applied on the protection metal film, and it is exposed and developed to a prescribed pattern. At this time, in a plan view of the crystal wafer, the photosensitive resist remains in the part to be the crystal piece **121**. Thereafter, the crystal wafer is soaked in an etching solution to be etched. In the manner described above, a plurality of crystal pieces **121** with a part thereof being connected can be formed within the crystal wafer. As described above, the angles between the main surface of the protrusion and the side faces are determined according to the cut angles of the crystal wafer. For example, through using an AT-cut plate cut out in parallel to the XZ' plane by rotating the crystal within a range of 30° to 50°, both inclusive, about the X-axis, it becomes possible to make the angle between the main surface of the first protruded section **122***a* and the first side face S**11** as 135° to 155°, the angle between the main surface of the first protruded section **122***a* and the second side face S**12** as 150° to 170°, the angle between the main surface of the second protruded section **122***b* and the third side face S**13** as 150° to 170°, and the angle between the main surface of the second protruded section **122***b* and the fourth side face S**14** as 135° to 155°. Further, through using an AT-cut plate cut out in parallel to the XZ' plane by rotating the crystal within a range of 35° 15' about the X-axis, it becomes possible to make the angle between the main surface of the first protruded section **122***a* and the first side face S**11** as 147°, the angle between the main surface of the first protruded section **122***a* and the second side face S**12** as 160°, the angle between the main surface of the second protruded section **122***b* and the third side face S**13** as 160°, and the angle between the main surface of the second protruded section **122***b* and the fourth side face S**14** as 147°.

Next, examples of each size of the crystal piece **121** will be described. The crystal piece **121** in a plan view is in a substantially rectangular shape, and the size of the long sides is 0.4 mm to 1.0 mm and the size of the short sides is 0.3 mm to 0.7 mm. The main surface of the first protruded section **122***a* is in a substantially rectangular shape, and the size thereof in parallel to the long side of the crystal piece **121** is 0.2 mm to 0.8 mm while the size thereof in parallel to the short side of the crystal piece **121** is 0.2 mm to 0.6 mm. The main surface of the second protruded section **122***b* is in a substantially rectangular shape, and the size thereof in parallel to the long side of the crystal piece **121** is 0.2 mm to 0.8 mm while the size thereof in parallel to the short side of the crystal piece **121** is 0.2 mm to 0.6 mm. The distance (the thickness of the oscillation section **122** in the vertical direction) from the main surface of the first protruded section **122***a* to the second protruded section **122***b* is 30 μm to 70 μm. Further, the thickness of the peripheral section **124** in the vertical direction is 10 μm to 65 μm.

The distance D**11** (+) from the prescribed other side of the crystal piece **121** to the first side face S**11** located on the positive direction side of the X-axis is 2 μm to 199 μm, and the distance D**11** (−) from the prescribed other side of the crystal piece **121** to the first side face S**11** located on the negative direction side of the X-axis is 30 μm to 200 μm. The distance D**12** (+) from the prescribed other side of the crystal piece **121** to the second side face S**12** located on the positive direction side of the X-axis is 230 μm to 900 μm, and the distance D**12** (−) from the prescribed other side of the crystal piece **121** to the second side face S**12** located on the negative direction side of the X-axis is 231 μm to 952 μm. The distance D**13** (+) from the prescribed other side of the crystal piece **121** to the third side face S**13** located on the positive direction side of the X-axis is 2 μm to 199 μm, and the distance D**13** (−) from the prescribed other side of the crystal piece **121** to the third side face S**13** located on the negative direction side of the X-axis is 30 μm to 200 μm. The distance D**14** (+) from the prescribed other side of the crystal piece **121** to the fourth side face S**14** located on the positive direction side of the X-axis is 230 μm to 900 μm, and the distance D**14** (−) from the prescribed other side of the crystal piece **121** to the fourth side face S**14** located on the negative direction side of the X-axis is 231 μm to 965 μm.

The metal pattern **125** provided to such crystal piece **121** is for applying a voltage from the outside of the crystal element **120**. The metal pattern **125** may be of a single layer or may be constituted with a plurality of stacked metal layers. Although not shown, the metal pattern **125** is formed with a first metal layer and a second metal layer stacked on the first metal layer, for example. A metal that can be closely stuck to the crystal is used for the first metal layer. For example, one selected from nickel, chrome, and titanium can be used. The use of the metal that is closely stuck to the crystal makes it possible to use a metal material that is hardly stuck to the crystal for the second metal layer. For example, one selected from gold, an alloy containing gold, silver, and an alloy containing silver can be used for the second metal layer. As described, a material that is stable and of relatively low electric resistivity is used for the second metal layer among the metal materials. By using the material of relatively low electric resistivity, the resistivity of the metal pattern **125** itself can be lowered. As a result, it becomes possible to suppress the increase in the equivalent series resistance value of the crystal element **120**. Further, with the use of the stable metal material for the second metal layer, the weight of the metal pattern **125** changes due to reaction with the air in the surrounding of the crystal element **120**. As a result, changes in the frequency of the crystal element **120** can be decreased.

The excitation electrodes **126** are for applying voltages to the oscillation section **122**. The excitation electrodes **126** are in a pair. One of the excitation electrodes **126** is provided on the top surface of the oscillation section **122** (the main surface of the first protruded section **122***a*), and the other excitation electrode **126** is provided on the bottom surface of the oscillation section **122** (the main surface of the second protruded section **122***b*). In a plan view of the crystal element **120**, the excitation electrode **126** is in a substantially rectangular shape. Further, one of the excitation electrodes **126** is provided in such a manner that the outer edge thereof is located on the inner side than the outer edge of the first protruded section **122***a*, while the other excitation electrode **126** is provided in such a manner that the outer edge thereof is located on the inner side than the outer edge of the second protruded section **122***b*.

The wiring sections **127** are in a pair, which are for applying voltages to the excitation electrodes **126** and provided on the surface of the crystal element **121**. One end of the wiring sections **127** is connected to the excitation electrode **126**, and the other end is connected to the leading section **128** that is provided along a prescribed side of the crystal piece **121**.

The leading sections **128** are connected to the wiring sections **127**. In a case where the crystal element **120** is used as a crystal device, the leading sections **128** are electrically bonded to the loading pad **111** provided on the top surface of the base unit **110***a* via the conductive adhesive **140**. The leading sections **128** are in a pair and provided side by side along a prescribed side of the crystal piece **121**.

Now, a method for forming the metal pattern **125** constituted with the excitation electrodes **126**, the wiring sections **127**, and the leading sections **128** on the crystal piece **121** will be described. Herein, described is a case where the metal pattern **125** is formed integrally by using a photolithography technique and an etching technique. First, a crystal wafer in a state where the parts to be the crystal pieces **121** are connected is prepared, and a metal film to be the metal pattern **125** is formed on both main surface of the crystal wafer. Then, a photosensitive resist is applied on the metal film, and it is exposed and developed to a prescribed pattern. At this time, the photosensitive resist remains in the part to be the metal pattern **125** after development. Thereafter, the crystal wafer is soaked in a prescribed etching solution to remove the metal film in the part where no photosensitive resin remains and, at last, the remained photosensitive resist is removed. In the manner described above, the metal pattern **125** is formed in a prescribed part of the crystal piece **121**. While the case of simultaneously forming the excitation electrodes **126**, the wiring sections **127**, and the leading sections **128** has been described, each of those may also be formed individually. Also, those may be formed using a sputtering technique, a vapor technique, or a combination of a photolithography technique and an etching technique, and a sputtering technique or a vapor technique without using a photolithography technique or an etching technique.

The crystal element **120** according to the exemplary embodiment includes: the crystal piece **121** in a substantially rectangular shape in a plan view, which includes the oscillation section **122** including the first protruded section **122***a* and the second protruded section **122***b* projected to the mutually opposing directions and the peripheral section **124** that is thinner than the oscillation section **122** and disposed along the outer edge of the oscillation section **122**; a pair of excitation electrodes **126** provided on the top surface of the first protruded section **122***a* and the bottom surface of the second protruded section **122***b*; a pair of leading sections **128** provided side by side along a prescribed side of the crystal piece **121**; and the wiring section **127** whose one end is connected to the excitation electrode **126** and the other end is connected to the leading section **128**. Further, the first protruded section **122***a* includes: the first side face S**11** that is sloping with respect to the top surface of the first protruded section **122***a* where the excitation electrode **126** is provided; and the second side face S**12** that is opposing to the first side face S**11** in a prescribed direction and opposing to the top surface of the first protruded section **122***a* where the excitation electrode **126** is provided. The second protruded section **122***b* includes: the third side face S**13** that is sloping with respect to the bottom surface of the second protruded section **122***b* where the excitation electrode **126** is provided; and the fourth side face S**14** that is opposing to the third side face S**13** in a prescribed direction and opposing to the bottom surface of the second protruded section **122***b* where the excitation electrode **126** is provided. In a plan view in the thickness direction of the crystal piece **121**, the first side face S**11** is disposed to overlap with the third side face S**13**, while the second side face S**12** is disposed to overlap with the fourth side face S**14**.

With this, when oscillation is propagated from the part sandwiched between the excitation electrodes **126** to the direction from the outer edge of the excitation electrodes **126** toward the outer edge of the oscillation section **122** in a plan view of the crystal element **120**, the angle between the propagating direction and the side face (the first side face S**11**, the second side face S**12**, the third side face S**13**, or the fourth side face S**14**) can be made smaller compared to the case where the side face (the first side face S**11**, the second side face S**12**, the third side face S**13**, or the fourth side face S**14**) is perpendicular. Therefore, the amount reflected at the first side face S**11**, the second side face S**12**, the third side face S**13**, and the fourth side face S**14** can be decreased, so that the deterioration amount of the electric characteristic caused by the oscillation reflected at the first side face S**11**, the second side face S**12**, the third side face S**13**, and the fourth side face S**14** can be suppressed.

Further, in the crystal element **120** according to the exemplary embodiment, the first side face S**11** is located on the positive direction side of the X-axis of the crystalline axes of the crystal piece **121** and in parallel to the surface perpendicular to the X-axis, the second side face S**12** is located on the negative direction side of the X-axis of the crystalline axes of the crystal piece **121** and in parallel to the surface perpendicular to the X-axis, the third side face S**13** is located on the positive direction side of the X-axis of the crystalline axes of the crystal piece **121** and in parallel to the surface perpendicular to the X-axis, and the fourth side face S**14** is located on the negative direction side of the X-axis of the crystalline axes of the crystal piece **121** and in parallel to the surface perpendicular to the X-axis. That is, in the plan view of the crystal piece **121**, the first side face S**11** is located on the positive direction side with respect to the virtual line CLU which passes the center CU of the main surface of the first protruded section **122***a* and is perpendicular to the X-axis, the second side face S**12** is located on the negative direction side with respect to the virtual line CLU which passes the center CU of the main surface of the first protruded section **122***a* and is perpendicular to the X-axis, the third side face S**13** is located on the positive direction side with respect to the virtual line CLU which passes the center CU of the main surface of the second protruded section **122***b* and is perpendicular to the X-axis, and the fourth side face S**14** is located on the negative direction side with respect to the virtual line CLU which passes the center CU of the main surface of the second protruded section **122***b* and is perpendicular to the X-axis.

With this, oscillation reflected at the side face (the first side face S**11**, the second side face S**12**, the third side face S**13**, or the fourth side face S**14**) can be decreased, so that the influence imposed upon the thickness slip vibration of the part sandwiched between the excitation electrodes **126** can be suppressed. Therefore, the deterioration amount of the electric characteristic can be suppressed. In general, when a voltage is applied to the excitation electrodes **126** and a part of the oscillation section **122** sandwiched between the excitation electrodes **126** is thickness-slip-vibrated, the vibration displacement becomes the greatest in the center part in the direction in parallel to the X-axis. Thus, the oscillation reflected and propagated from the side face in a direction in parallel to the X-axis tends to influence the thickness slip vibration of the part sandwiched between the excitation electrodes **126**. That is, the embodiment is designed to locate the first side face S**11** and the third side face S**13** in the vertical direction and locate the second side dace S**12** and the fourth side face S**14** in the vertical direction in the sectional view taken along the XY' plane (the surface in parallel to the X-axis and the Y'-axis) so that the influence of the oscillation reflected at the side face (the first side face S**11**, the second side face S**12**, the third side face S**13**, or the fourth side face S**14**) imposed on the thickness slip vibration of the part sandwiched between the excitation electrodes **126** can be more decreased compared to the case where those are located in the vertical direction in the sectional view of the Z'Y' plane. So, the deterioration amount of the electric characteristic can be suppressed.

Further, in the crystal element **120** according to the exemplary embodiment, the angle between the top surface of the first protruded section **122**a where the excitation electrode **126** is provided and the first side face S**11** is larger than 90° and smaller than 180° °. Specifically, it is 135° to 155°. Further, the angle between the top surface of the first protruded section **122**a where the excitation electrode **126** is provided and the second side face S**12** is larger than 90° and smaller than 180°. Specifically, it is 150° to 170°. Furthermore, the angle between the bottom surface of the second protruded section **122**b where the excitation electrode **126** is provided and the third side face S**13** is larger than 90° and smaller than 180°. Specifically, it is 150° to 170°. Further, the angle between the bottom surface of the second protruded section **122**b where the excitation electrode **126** is provided and the fourth side face S**14** is larger than 90° and smaller than 180°. Specifically, it is 135° to 155°.

With this, when oscillation is propagated from the part sandwiched between the excitation electrodes **126** to the direction from the outer edge of the excitation electrodes **126** toward the outer edge of the oscillation section **122** in a plan view of the crystal element **120**, the angle between the propagating direction and the side face (the first side face S**11**, the second side face S**12**, the third side face S**13**, or the fourth side face S**14**) can be made still smaller compared to the case where the side face (the first side face S**11**, the second side face S**12**, the third side face S**13**, or the fourth side face S**14**) is perpendicular. Therefore, the amount reflected at the first side face S**11**, the second side face S**12**, the third side face S**13**, and the fourth side face S**14** can be decreased, so that the deterioration amount of the electric characteristic caused by the oscillation reflected at the first side face S**11**, the second side face S**12**, the third side face S**13**, and the fourth side face S**14** can be suppressed further.

Further, in a plan view of the crystal element **120** according to the exemplary embodiment, the distance D**11** (+) from a side which is perpendicular to the X-axis and is a prescribed other side of the crystal piece **121** located on the positive direction side of the X-axis to a side of the first side face S**11** located on the positive direction side of the X-axis is shorter than the distance D**11** (−) from the prescribed other side to the first side face S**11** located on the negative direction side of the X-axis, and the distance D**13** (+) to a side of the third side face S**13** located on the positive direction side of the X-axis is shorter than the distance D**11** (−) from the prescribed other side to the first side face S**11** located on the negative direction side of the X-axis. Further, the distance D**14** (+) from a prescribed other side to the fourth side face S**14** located on the positive direction side of the X-axis is shorter than the distance D**14** (−) from the prescribed other side to a side of the fourth side face S**14** located on the negative direction side of the X-axis, and the distance D**14** (+) from the prescribed other side to a side of the fourth side face S**14** located on the positive direction side of the X-axis is shorter than the distance D**12** (−) to a side of the second side face S**12** located on the negative direction side of the X-axis. That is, in the crystal piece **121**, assuming that the side perpendicular to the X-axis located on the positive direction side of the X-axis with respect to the virtual lines CLU and CLD is the prescribed other side of the crystal piece **121**, the distance (D**13** (+)) from the prescribed other side to the side of the third side face S**13** close to the prescribed other side is shorter than the distance (D**11** (−)) from the prescribed other side to the side of the first side face S**11** distant from the prescribed other side, and the distance (D**14** (+)) from the prescribed other side to the side of the fourth side face S**14** close to the prescribed other side is shorter than the distance (D**12** (−)) from the prescribed other side to the side of the second side face S**12** distant from the prescribed other side.

With this, when oscillation is propagated from the part sandwiched between the excitation electrodes **126** to the direction from the outer edge of the excitation electrodes **126** toward the outer edge of the oscillation section **122** in a plan view of the crystal element **120**, the angle between the propagating direction and the side face (the first side face S**11**, the second side face S**12**, the third side face S**13**, or the fourth side face S**14**) can be made smaller compared to the case where the side face (the first side face S**11**, the second side face S**12**, the third side face S**13**, or the fourth side face S**14**) is perpendicular. Therefore, the amount reflected at the first side face S**11**, the second side face S**12**, the third side face S**13**, and the fourth side face S**14** can be decreased, so that the deterioration amount of the electric characteristic caused by the oscillation reflected at the first side face S**11**, the second side face S**12**, the third side face S**13**, and the fourth side face S**14** can be suppressed.

In the crystal element **120** according to the exemplary embodiment, in a sectional view of the crystal piece **121** taken along the XY' plane (the plane in parallel to the X-axis and the Y'-axis), the distance D**11** (−) from the prescribed other side of the crystal piece **121** to the first side face S**11** located on the negative direction side of the X-axis and the distance D**13** (−) from the prescribed other side of the crystal piece **121** to the third side face S**13** located on the negative direction side of the X-axis are equivalent. Further, in the crystal piece **121**, the distance D**12** (+) from the prescribed other side of the crystal piece **121** to the second side face S**12** located on the positive direction side of the X-axis and the distance D**14** (+) from the prescribed other side of the crystal piece **121** to the fourth side face S**14** located on the positive direction side of the X-axis are equivalent. That is, in the crystal piece **121**, the distance (D**11** (−)) from the prescribed other side to the side of the first side face S**11** distant from the prescribed other side is equivalent to the distance (D**13** (−)) from the prescribed other side to the side of the third side face S**13** distant from the prescribed other side, and the distance (D**14** (+)) from the prescribed other side to the side of the second side face S**12** close to the prescribed other side is equivalent to the distance (D**12** (+)) from the prescribed other side to the side of the fourth side face S**14** close to the prescribed other side.

With such structure, in the perspective plan view of the crystal piece **120**, the first side face S**11** located on the negative direction side of the X-axis and the third side face S**13** located on the negative direction side of the X-axis can overlap with each other while the second side face S**12** located on the positive direction side of the X-axis and the fourth side face S**14** located on the positive direction side of the X-axis can overlap with each other. Therefore, the amount reflected at the first side face S**11**, the second side face S**12**, the third side face S**13**, and the fourth side face S**14** can be decreased. As a result, the deterioration amount of the electric characteristic caused by the oscillation reflected at the first side face S**11**, the second side face S**12**, the third side face S**13**, and the fourth side face S**14** can be suppressed.

The crystal device according to the exemplary embodiment is constituted with: the crystal element **120** in such structure; the element loading member **110** to which the crystal element **120** is mounted; and the lid **130** that is bonded to the element loading member **110** and air-tightly seals the crystal element **120**. This makes it possible to decrease changes in the electric characteristics caused when the oscillation propagated from a part of the crystal piece

121 sandwiched between the excitation electrodes **126** is reflected at the side faces of the first protruded section **122***a* and the second protruded section **122***b*. As a result, the equivalent series resistance value can be decreased.

The present invention is not limited only to the exemplary embodiment described above but may be embodied in various kinds of modes.

The crystal device having the crystal element is not limited to the crystal oscillator. For example, the crystal device may be an oscillator which includes, in addition to the crystal element, an integrated circuit element (IC) that generates oscillation signals by applying a voltage to the crystal element. Further, the crystal device may also be a device with a thermoset oven, for example. The structure of the element loading member for packaging the crystal element in the crystal device may be configured as appropriate. For example, the element loading member may be of an H-section type that includes recessed sections on the top surface and bottom surface thereof.

The shapes and sizes of the crystal element are not limited to those shown in the exemplary embodiment but may be set as appropriate. The shape of the excitation electrode is not limited to a substantially rectangular shape in a plan view. For example, the excitation electrode may be in an oval shape.

In a plan view of the crystal element, the centers of the first protruded section and the second protruded section may be consistent with the center of the crystal piece or may be decentered therefrom.

The virtual line passing through the center of the top surface of the oscillation section (the main surface of the first protruded section) in a plan view of the top surface of the crystal element and the virtual line passing through the center of the bottom surface of the oscillation section (the main surface of the second protruded section) in a perspective plan view of the bottom surface of the crystal element viewed from the top surface may or may not overlap with each other.

REFERENCE NUMERALS

110—Element loading member
110*a*—Base body
110*b*—Frame unit
111—Loading pad
112—External terminal
120—Crystal element
121—Crystal piece
122—Oscillation section
122*a*—First protruded section
122*b*—Second protruded section
123—Sloping section
123*a*—First slope
123*b*—Second slope
124—Peripheral section
125—Metal pattern
126—Excitation electrode
127—Wiring section
128—Leading section
130—Lid
140—Conductive adhesive
S**11**—First side face
S**12**—Second side face
S**13**—Third side face
S**14**—Fourth side face
D**11** (+), D**21** (+)—Distance between prescribed other side of crystal piece and side of first side face close to prescribed other side of crystal piece (distance from prescribed other side of crystal piece to first side face located on +X side)
D**11** (−), D**21** (−)—Distance between prescribed other side of crystal piece and side of first side face distant from prescribed other side of crystal piece (distance from prescribed other side of crystal piece to first side face located on −X side)
D**12** (+), D**22** (+)—Distance between prescribed other side of crystal piece and side of second side face close to prescribed other side of crystal piece (distance from prescribed other side of crystal piece to second side face located on +X side)
D**12** (−), D**22** (−)—Distance between prescribed other side of crystal piece and side of second side face distant from prescribed other side of crystal piece (distance from prescribed other side of crystal piece to second side face located on −X side)
D**13** (+), D**23** (+)—Distance between prescribed other side of crystal piece and side of third side face close to prescribed other side of crystal piece (distance from prescribed other side of crystal piece to third side face located on +X side)
D**13** (−), D**23** (−)—Distance between prescribed other side of crystal piece and side of third side face distant from prescribed other side of crystal piece (distance from prescribed other side of crystal piece to third side face located on −X side)
D**14** (+), D**24** (+)—Distance between prescribed other side of crystal piece and side of fourth side face close to prescribed other side of crystal piece (distance from prescribed other side of crystal piece to fourth side face located on +X side)
D**14** (−), D**24** (−)—Distance between prescribed other side of crystal piece and side of fourth side face distant from prescribed other side of crystal piece (distance from prescribed other side of crystal piece to fourth side face located on −X side)

What is claimed is:

1. A crystal element, comprising:

a crystal piece in a substantially rectangular shape in a plan view, which includes an oscillation section having a first protruded section and a second protruded section projected to mutually opposing directions and a peripheral section which is thinner than the oscillation section and provided along an outer edge of the oscillation section;

a pair of excitation electrodes provided on a top surface of the first protruded section and on a bottom surface of the second protruded section;

a pair of leading sections provided side by side along a prescribed side of the crystal piece; and

a wiring section whose one end is connected to the excitation electrode and other end is connected to the leading section, wherein:

the first protruded section includes a first planar side face extending directly from the top surface of the first protruded section to a top surface of the peripheral section and that is sloping with respect to the top surface of the first protruded section where the excitation electrode is provided, and a second planar side face extending directly from the top surface of the first protruded section to the top surface of the peripheral section and which is opposing to the first side face in a prescribed direction and opposing to the top surface of the first protruded section where the excitation electrode is provided;

the second protruded section includes a third planar side face extending directly from the bottom surface of the second protruded section to a bottom surface of the peripheral section and that is sloping with respect to the bottom surface of the second protruded section where the excitation electrode is provided, and a fourth planar side face extending directly from the bottom surface of the second protruded section to the bottom surface of the peripheral section and which is opposing to the third side face in a prescribed direction and opposing to the bottom surface of the second protruded section where the excitation electrode is provided;

the first side face is disposed to overlap with the third side face in a plan view of the crystal piece in a thickness direction; and

the second side face is disposed to overlap with the fourth side face in the plan view of the crystal piece in the thickness direction;

wherein an angle between the top surface of the first protruded section where the excitation electrode is provided and the first planar side face is larger than 135° and smaller than 155°;

an angle between the top surface of the first protruded section where the excitation electrode is provided and the second planar side face is larger than 150° and smaller than 170°;

an angle between the bottom surface of the second protruded section where the excitation electrode is provided and the third planar side face is larger than 150° and smaller than 170°; and

an angle between the bottom surface of the second protruded section where the excitation electrode is provided and the fourth planar side face is larger than 135° and smaller than 155°.

2. The crystal element as claimed in claim **1**, wherein, in a plan view:

the first side face is located on a positive direction side of an X-axis with respect to a virtual line which passes through a center of a main surface of the first protruded section and is perpendicular to the X-axis of crystalline axes of the crystal piece;

the second side face is located on a negative direction side of the X-axis with respect to the virtual line which passes through the center of the main surface of the first protruded section and is perpendicular to the X-axis;

the third side face is located on the positive direction side of the X-axis with respect to a virtual line which passes through a center of a main surface of the second protruded section and is perpendicular to the X-axis; and

the fourth side face is located on the negative direction side of the X-axis with respect to the virtual line which passes through the center of the main surface of the second protruded section and is perpendicular to the X-axis.

3. The crystal element as claimed in claim **2**, wherein, provided that a side which is perpendicular to the X-axis located on the positive direction side of the X-axis with respect to the virtual line is a prescribed other side of the crystal piece in a plan view of the crystal element:

a distance between the prescribed other side and a side of the third side face close to the prescribed other side is shorter than a distance between the prescribed other side and a side of the first side face distant from the prescribed other side; and

a distance between the prescribed other side and a side of the fourth side face close to the prescribed other side is shorter than a distance between the prescribed other side and a side of the second side face distant from the prescribed other side.

4. The crystal element as claimed in claim **3**, wherein:

a distance between the prescribed other side and the side of the first side face distant from the prescribed other side is equivalent to a distance between the prescribed other side and the side of the third side face distant from the prescribed other side; and

a distance between the prescribed other side and the side of the second side face close to the prescribed other side is equivalent to a distance between the prescribed other side and the side of the fourth side face close to the prescribed other side.

5. A crystal device, comprising:

the crystal element as claimed in claim **1**;

an element loading member to which the crystal element is mounted; and

a lid which is bonded to the element loading member for air-tightly sealing the crystal element.

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